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Review

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Review

How to describe a new species in zoology and avoid mistakes

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ABSTRACT

Taxonomy is the science of discovering, naming, describing, diagnosing, identifying, and classifying different kinds of taxa, from species to families. It lays the foundation for all of the biological sciences. The rapid increase in both taxonomic descriptions and malpractice in recent decades indicates a need for consistency in the procedure and quality of taxonomic research publications dealing with recognition of new taxa, name changes, and nomenclatural acts. Indeed, there are numerous examples in the recent literature of taxonomic works that fall short of the basic procedures and minimum standards required for naming new species according to the mandatory provisions and recommendations of the *International Code of Zoological Nomenclature*, accepted standards of taxonomic best practice, and journal editorial policy. Here, we provide practical guidelines of the procedure and key elements required to name, describe, and publish a new animal species or revise the taxonomic status of a species. We then discuss some of the common pitfalls that should be avoided. Mistakes commonly made include failure to read the *Code*, to review the primary taxonomic literature, to examine type material, to construct the taxon name correctly, to explicitly establish the new taxon, to provide adequate typification, to clearly differentiate the new taxon, to register the publication of the new taxon name in ZooBank, or to publish the name of the new taxon in a manner that is compliant with the *Code*. We provide some examples of these mistakes, mainly from butterflies (Insecta: Lepidoptera: Papilionoidea) and, to some extent, reptiles because these taxon groups seem to have an unusually high level of poor taxonomic practice.

Keywords: code; description; new species; nomenclature; taxonomy; zoology

INTRODUCTION

> *Without taxonomy to give shape to the bricks, and systematics to tell us how to put them together, the house of biological science is a meaningless jumble.*
>
> Lord Robert M. May (1990)

Taxonomy is the science of discovering, naming, describing, diagnosing, documenting, recognizing, identifying, and classifying different kinds of organisms (Mayr 1969, Mayr and Ashlock 1991). It is often viewed as a subset of systematics, which is the science that seeks to explore relationships between species in an evolutionary context by providing the framework into which species are classified—a categorical arrangement that gives order to the nature and patterns of variation of life on Earth. Taxonomy provides the international language for scientific communication, establishing clear, universal, and unambiguous terms of reference. It underpins all fields in the biological sciences, laying the foundation for ecology, evolutionary biology, conservation biology, biosecurity, primary industry (agriculture, aquaculture, and fisheries), medicine, and public health, all of which depend on a robust taxonomy (e.g. Kitching 1993, Winston 1999, 2018, Godfray 2002, Mallet and Willmott 2003, Wheeler *et al.* 2004, Wilson 2004, Costello *et al.* 2013, Vane-Wright 2013, Braby and Williams 2016, Taxonomy Decadal Plan Working Group 2018, Hamilton *et al.* 2021, Löbl *et al.* 2023).

Descriptive taxonomy (alpha taxonomy) includes three main tasks: (i) generating species-level taxonomic hypotheses and recognizing or delimiting the boundaries of these taxa through acquisition of evidence and rigorous hypothesis-testing according to a given species' concept; (ii) proposing new scientific names,

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making nomenclatural acts, and proposing taxonomic opinions (name changes) based on a set of rules and recommendations that ought to be followed; and (iii) publication based on a set of procedures or protocols for best practice. Nomenclatural acts include type fixations or designations (typification), whereas taxonomic opinions cause species' names to change. The names of species change for various reasons (Mallet and Willmott 2003, Knapp *et al.* 2004, Thiele *et al.* 2021), but the main changes include synonymy, status revision, and new combinations, as illustrated by the following scenarios. Suppose a taxonomist is investigating the boundaries of a species group or complex using an evidence-based hypothesis testing framework. Suppose further that the null hypothesis (H_0) is that the complex comprises only a single species, whereas the alternative hypothesis (H_1) holds that there are two species (Braby *et al.* 2012). Although in this simple case there are only two possible taxonomic conclusions, there are seven possible decisions or outcomes using such a framework (Table 1). For example, it may turn out that what was previously considered to be two species is in fact one species, in which case the younger species' name needs to be to be placed into the synonymy of the older species' name as a junior synonym. Alternatively, what was previously considered to be a single species may in fact comprise two species (i.e. reject H_0 and accept H_1). If both species have species' names, then it is simply a matter of revising the status of the nomen currently in synonymy so that it is reinstated. If it turns out that one of the species does not have a binomen, then it needs to be formally named and described as new to become available and valid. On the other hand, the taxonomic research may provide evidence to indicate that there is a single species (i.e. accept H_0) that is misclassified and needs to be reclassified and transferred from the group in which it was originally described to a group that better reflects its true phylogenetic relationships.

The procedures dealing with taxonomic research that lead to nomenclatural changes, such as the recognition of new species and name changes based on taxonomic opinions, is, in our experience, where most pitfalls and problems arise in taxonomic publications. For any taxonomic publication, there are basically four different sets of rules and principles that need to be considered: (i) articles of the relevant code of nomenclature; (ii) recommendations of the code of nomenclature; (iii) accepted standards of taxonomic best practice; and (iv) journal editorial policy and author guidelines. Schenk and McMasters (1948) provided international guidelines for taxonomic best practice and publication, including an outline for the description of a new species (on p. 25), in relation to the first edition of the *International Code of Zoological Nomenclature*. However, that pioneering work is now considerably out of date. Mayr's (1969) classic work on systematic zoology included a detailed chapter on how to prepare a taxonomic publication, as well as a

Table 1. Hypothesis testing and possible taxonomic decisions based on revision of a species complex involving one or two species.

Hypothesis	Number of species (before revision)	Number of species (after revision)	Taxonomic decision
H_0 (1 species)	1	1	none
	1	1	new combination (**comb. nov.**) The investigated species is found to be a member of a genus that is different from its original or current combination and is transferred to that genus.
	2	1	new synonymy (**syn. nov.**) The investigated species is found to be identical to another named species, and the binomen of that 2nd species is older. The younger species' name is placed into the synonymy of the older species' name as a junior synonym.
H_1 (2 species)	1	2	none The investigation reveals the presence of two species, both with available and valid names, but the 2nd species was previously unknown from study region.
	1	2	revised status (**stat. rev.**). The investigation reveals the presence of two species, both with available names, but the binomen of the 2nd species is currently in synonymy with the other species. The 2nd species is removed from synonymy and redescribed as a valid species.
	1	2	reinstated status (**reinst. stat.**) The investigation reveals the presence of two species, but the binomen of one species was previously valid but is currently in synonymy. The previously synonymized name is removed from synonymy and made valid again.
	1	2	new species (**sp. nov.**) The investigation reveals the presence of two species, one of which does not have a binomen. The unnamed species is named and described as new.

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transcript of the second (1964) edition of the *International Code of Zoological Nomenclature*. More recently, Winston (1999) published a comprehensive manual of best practice for describing new species and an overview of the international zoological and botanical codes of nomenclature. Some of the concepts of best practice were expanded upon by Dubois (2005), Kaiser (2013), Kaiser *et al.* (2013), Wüster and Kaiser (2023), and Denzer and Kaiser (2023). Šlapeta (2013) provided brief guidelines to assist with describing and publishing a new species. However, there is no modern account that sets out succinctly how species ought to be named, described, or revised and published (but see: Winston 1999: 84–86). With the rapid increase in both taxonomic publications and species' descriptions or delineation in recent decades (Isaac *et al.* 2004, Joppa *et al.* 2011, Bacher 2012, Costello *et al.* 2013, 2015a, b) there is a pressing need for consistency in the procedure, nomenclature, and quality of taxonomic papers, which has been clearly lacking in several works (Wüster *et al.* 2021). Hence, the aim and main focus of this paper is to provide practical guidelines of the procedure and components required to describe and publish a new species or to revise the taxonomic status of a species, especially scientists new to the field of taxonomy (students or individuals without access to mentors) and editors of journals that publish taxonomic works. Before discussing the important elements of a taxonomic paper, we briefly comment on nomenclature because it is an important adjunct to taxonomy. In this work, we limit our discourse to zoology.

ZOOLOGICAL NOMENCLATURE

Each organism has a unique scientific name that is composed of two parts, generic and specific, which is referred to as the binominal system (ICZN 1999, Knapp *et al.* 2004), often incorrectly referred to as the 'binomial' system (Schenk and McMasters 1948). The generic or genus name forms the group name and is always a noun. The specific name is the descriptive part and may be a noun or an adjective. For animals, the zoological nomenclatural system started with the 10th edition of Linnaeus' *Systema Naturae* published in 1758 (Winston 1999, 2018, Knapp *et al.* 2004).

The nomenclature of most organismal Kingdoms is supported by a set of rules and recommendations, referred to as codes (Mayr 1969, Mayr and Ashlock 1991, Knapp *et al.* 2004). There are three separate international codes of nomenclature, all of which operate independently. For animals, the relevant code is the *International Code of Zoological Nomenclature* published by the International Commission on Zoological Nomenclature (ICZN), which was established in 1895, and ratified by the International Union of Biological Sciences. Because the codes are independent, the same taxon name can be used as valid in each code. For example, the generic name *Pieris* has been used for both animals and plants—in zoology the genus *Pieris* Schrank, 1801 is an insect (butterfly) in the family Pieridae, whereas in botany the genus *Pieris* D.Don is a vascular flowering plant in the family Ericaceae.

The *International Code of Zoological Nomenclature* (hereafter referred to as the *Code*) is currently in its fourth edition (ICZN 1999). The next (fifth) edition of the *Code* is expected to be published later this decade (Rheindt *et al.* 2023). The *Code* is a system or convention, not a science (Knapp *et al.* 2004, Dubois 2005, Kaiser 2013, Winston 2018), and it deals with the regulation of names at three different hierarchical levels: family-group names, genus-group names, and species-group names. The *Code* regulates these names according to a set of carefully constructed articles, with the overarching goal of providing stability and universality to nomenclature based on certain underlying principles (Knapp *et al.* 2004, Polaszek and Wilson 2005, Winston 2018, Ceríaco *et al.* 2023). The articles consist of rules, which are mandatory provisions, and recommendations, which are advisory statements for best practice. The rules include information on what taxonomic ranks are considered to be valid, how scientific names must be constructed and spelt, how capitalization is to be used, how authorities of names (i.e. the author's name of a taxon) are to be constructed to avoid ambiguity, and what abbreviations must be used for new nomenclatural acts. For instance, if the generic assignment of a species has been changed so that the new combination differs from the original combination, then the authority citation (and date, if cited) of the species is placed in parentheses. Other rules include details on typification (designation of type specimens and fixation of names), synonymy, principle of priority (use of different names for the same taxon is prohibited), principle of homonymy (use of the same name for different taxa is prohibited), emendation (intentional change in the original spelling of an available name), principle of the first reviser, reversal of precedence, and gender agreement among other matters when dealing with existing names. Importantly, the *Code* makes a clear distinction between available names and valid names. A species may have many available names but only one valid name, which is the correct name for the taxon in an author's taxonomic judgement.

It is crucial to emphasize that the *Code* only regulates the use of names and does not interfere with the quality of science or process of taxonomy, such as the data (evidence) used to delimit species and identify independent evolutionary lineages, regardless of the quality of the work (Wüster *et al.* 2001, Knapp *et al.* 2004, Borrell 2007, Krell 2021, Wüster *et al.* 2021). In other words, the *Code* is scientifically neutral and does not interfere with scientific opinion or judgment. The *Code* also has a Code of Ethics (listed under Appendix A), which provides a set of recommendations on various matters, such as avoidance of offensive names, and how to proceed if it is discovered that another person is working on the same undescribed taxon, but these cannot be enforced.

THE KEY ELEMENTS OF A TAXONOMIC PAPER

For a new specific group name (i.e. species or subspecies) to be available and valid under the current edition of the *Code*, there are four basic elements or criteria that need to be met: (i) the name of the new species (in Latin or latinized) and a clear indication that it is intended to be new by the author; (ii) the designation or fixation of a holotype; (iii) a description and/or diagnosis that purports to differentiate the taxon; and (iv) scientific publication in a manner that ensures multiple identical copies of the work containing the name are freely available or by purchase. However, to satisfy both the rules and recommendations of the ICZN *and* the accepted standards of scientific best practice and journal editorial policy, the following list of items, in our view, constitutes the minimum set of information required

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Table 2. Example of how to set out the classification headers (higher-level taxon names), type species, species' name header, figures, and synonymy of a species and subspecies (modified from Beaver *et al.* 2023).

LYCAENIDAE Leach, 1815

OGYRINI Waterhouse & Lyell, 1914

Ogyris Angas, 1847

Type species: *Ogyris amaryllis* Hewitson, 1862 by subsequent monotypy.

Ogyris arcana M.R.Williams & Hay, 2001 **stat. rev.**
(Figs. 1, 3e–h, 6e–h)

Ogyris otanes C.Felder & R.Felder, 1865.—Waterhouse & Lyell, 1914: 121; Waterhouse, 1932: 184; Common & Waterhouse, 1972: 342; Williams *et al.*, 1992: 55–60; Hay *et al.* [1994]: 31, pl. 4, fig. 7–9. [Genus *Ogyris* Westwood, 1851]. [Misidentifications in literature].

Ogyris sp.—Field, 1987: 113.

Ogyris otames C.Felder & R.Felder, 1865.—Hay, 1989: 42, 43. [Misspelling of *O. otanes*].

Ogyris otanes C.Felder & R.Felder, 1865 'local forms 2 and 3'.—Dunn and Dunn, 1991: 367. [Genus *Ogyris* Westwood, 1851].

Ogyris otanes (C.Felder & R.Felder, 1865) 'south-western form'.—Braby, 2000: 710–712, pl. 50, fig. 3b. [Genus *Ogyris* Angas, 1847].

Ogyris otanes (C.Felder & R.Felder, 1865).—Williams *et al.*, 2012: 50–51. [Misidentification in literature]. [Genus *Ogyris* Angas, 1847].

Ogyris otanes arcana M.R.Williams & Hay, 2001: 59–61, fig. 5–8; Sands & New, 2002: 288; Braby, 2010: 35; Schmidt *et al.*, 2014: 473–484; Braby, 2016: 266–267, 350; Sankowsky, 2020: 315.

Ogyris halmaturia waterhouseri (Bethune-Baker, 1905) **stat. rev.**
(Figs. 1, 4g–l, 7e–h.)

Ogyris idmo Hewitson, 1862.—Miskin, 1890: 24; Anderson & Spry, 1893: 101, 104; Lower, 1893: 9; Waterhouse, 1903a: 29. [Misidentifications in literature or incorrectly considered to be a senior synonym of *O. halmaturia*].

Ogyris waterhouseri Bethune-Baker, 1905: 273–274; Waterhouse and Lyell, 1908: 162, 165–166; Kershaw, 1908: 163–164; Seitz, 1926: 940; Peters, 1971: 26. [Genus *Ogyris* Westwood, 1851].

Ogyris waterhouseri (Bethune-Baker, 1905).—Braby and Douglas, 2008: 315–329, fig. 1–3, 14–17. [Genus *Ogyris* Angas, 1847].

Ogyris idmo waterhouseri Bethune-Baker, 1905. — Waterhouse & Lyell, 1914: 122, pl. 18; Burns, 1931: 131–132; Common, 1964: 96; Burns & Rotherham, 1969: 98; D'Abrera, 1971: 320; McCubbin, 1971: 84; Quick, 1972: 9–10.

Ogyris idmo waterhousei Bethune-Baker, 1905.—Common, 1964: 96. [Misspelling of *O. waterhouseri*].

Ogyris halmaturia waterhouseri Bethune-Baker, 1905.—Tindale, 1923: 348.

Ogyris idmo halmaturia Tepper, 1890.—Waterhouse, 1932: 179–180;Common and Waterhouse, 1972: 341–342; Crosby, 1974a: 65; Fisher, 1978: 193–194, pl. 10, fig. 11–13; Common and Waterhouse, 1981: 479; Dunn and Dunn, 1991: 366, 457; Douglas, 1995: 6–10, fig. 1; Grund, 1999: 47–48; Grund, 2003: 71. [Genus *Ogyris* Westwood, 1851]. [Considered to be a senior synonym of *O. waterhouseri*].

Ogyris idmo halmaturia (Tepper, 1890).—Edwards, 1996: 250; Hunt *et al.*, 1998: 113–116; Moore, 1999: 12; Field, 1999: 252–254, 259, fig. 13–16; Braby, 2000: 396, 712–714, pl. 50, fig. 5b; Edwards *et al.*, 2001: 254–255; Sands and New, 2002: 282–284; Braby, 2004: 242–243, 316; New *et al.*, 2007: 245. [Genus *Ogyris* Angas, 1847]. [Considered to be a senior synonym of *O. waterhouseri*].

Ogyris halmaturia (Tepper, 1890).—Grund, 2010: 114–120; Braby *et al.*, 2011: 29–36; New, 2011: 21, 99, 103–104, 148; Schmidt *et al.*, 2014: 473–484; Braby, 2016: 268–269, 350. [Genus *Ogyris* Angas, 1847].

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for a taxonomic publication, whether it be of a new species, review of a species group or revision of a genus or higher rank (see also: Winston 1999). There is generally a set order of how the items are arranged as headings and subheadings, although this is by no means universal, and each publication has its own style of how taxonomic papers are structured. The following order provides a logical and coherent framework for the key elements of a taxonomic work.

Classification header

The higher-level taxon name, together with the authority citation and date, are listed as a heading (Table 2). Often two headings are given: the family-group name is listed first, followed by the genus-group name as a second heading. However, some journals require other higher categories of classification as headings, for example, names of the superfamily, subfamily, tribe or subtribe to which the species belongs.

Type species: Every genus (and subgenus) must have a type species, and it should be listed below the genus-group name with a statement of how it was designated (Table 2). Type species of genera are fixed in several ways, but the most common three are: (i) by original designation, which means by the describer (author) in the original publication; (ii) by monotypy, which means by the author when only a single species was placed in a genus in the original publication; or (iii) by subsequent designation, which means by a reviser when two or more species were assigned to a genus for which no type species was fixed in the original publication. For new genera, it must be clearly indicated that a type species is being designated for the first time, for example, by the term 'type species' and the name should be given in its original binomen.

Species' name header

If the species has not previously been named, then two elements are required in the heading for the species' name: (i) the taxon name in binominal form; followed by (ii) the term 'sp. nov.', 'sp. n.', 'new species', or 'species nova'. The abbreviations **sp. nov.** or **sp. n.** actually mean species nova or new species, and one of these terms must follow the taxon name to indicate explicitly that the author is proposing a name for a species new to science. If one author or a subset of authors of a multi-authored paper are describing the new species, then those author(s) must appear after the new name, followed by a comma, and then the term 'sp. nov.' or 'sp. n.', so that is clear who is the author(s). Once a new species has been described and diagnosed, subsequent reference to the species in the manuscript need not include 'sp. nov.', except in the captions of the Tables and Figures.

If, however, the species has previously been named and is being revised, then four elements are required in the heading for the species' name: (i) the taxon name in binominal form; (ii) the authority citation; (iii) the date of publication; and (iv) the kind of taxonomic change being made, which appears as a term after the year (Table 2). The authority citation is given by the person's family name and the date as the year of publication; if there are two authors, both author names are cited and joined by 'and' or an ampersand '&'. If there are more than three authors, then the first author is followed by '*et al.*'. For taxonomic changes, the main terms commonly used are 'comb. nov.', 'stat. rev.', and 'syn. nov.'. The term **comb. nov.** is used for a new combination (e.g. species' name transferred to a genus that is different from its original combination); **stat. rev.** is used for revised status (e.g. subspecies' name treated as full species' name); and **syn. nov.** is used for a new synonymy (e.g. species' name considered to be a junior synonym and, therefore, invalid). Another frequent abbreviation is **reinst. stat.**, meaning, for instance, a previously synonymized name that is made valid again, or a name previously downgraded to subspecies status that is restored to valid species status. Combinations of these abbreviations ought to be used when two or more changes are made, for example, **syn. nov. et stat. rev.** means that a species is being placed in synonymy but treated as a valid taxon (e.g. subspecies); **stat. rev. et comb. nov.** means that the status of a species is being revised and transferred to a different genus. It should be noted that these terms are guidelines only according to journal editorial policy (e.g. the author guidelines) and are not considered by the *Code* (see Recommendation 16A: means of explicitly indicating names as intentionally new).

The following information should be included under the heading of the taxon name and authority citation.

Figures: New or revised species ought to be illustrated and referred to in the figures, with figure numbers listed in the first line after the species' name heading (Table 2). Although the illustrations do not need to include the name-bearing type specimen, best practice is to include types and many journals now insist on this. Illustrations of types (and their labels) of previously named species and junior synonyms are not essential, but they can be particularly useful if there is doubt over their existence, authenticity, or identity.

ZooBank registration number: For papers published in electronic only (online) journals, it is now mandatory for the work to be registered in ZooBank prior to publication (ICZN 2012). The *Code* does not require registration of the new taxa, although most journals now require that newly described species (as well as new genera, subgenera, and subspecies) also be registered in ZooBank. Once registered, the ZooBank registration number must be listed in the publication itself.

Type locality: The place of origin from which the name-bearing type specimen (holotype, lectotype, or neotype) was collected defines the type locality for that species, and it must be given.

Synonymy. The synonymy section is a critically important part of the paper, and it must be understood clearly. The synonymy consists of a summary of the full history of the nomenclature of the species—all the species' names and combinations used, plus as complete a list of all previous references pertaining to the species as possible (Table 2). It also provides the author's conclusions regarding taxonomic assignment of the species and to the validity of names that have been applied by previous workers in the past. The style or convention used for the synonymy varies according to the journal, but it is customary to cite in chronological order: (i) the species' name; and for each name (ii) the bibliographic reference, including the author, date (year) of publication, and page number(s) and/or figure or plate number(s). For example, Hay *et al.* [1994], on page 31 and plate 4, figures 7–9, referred to the species *Ogyris arcana* M.R.Williams & Hay, 2001 under the

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name *O. otanes* C.Felder & R.Felder, 1865 (Table 2). Generally, the synonymy section only applies to established species that are being revised and it is not required for new species. However, for a new species that was previously confused with another species, there may be a history of names in which the species was previously classified—these constitute misidentifications and they ought to be included as 'misidentifications in the literature'.

Material examined

Type material: The type specimens examined should be listed along with their deposition for all name-bearing types (holotype, lectotype, or neotype). When designating a holotype, the specimen should be clearly labelled in a way that will unmistakably identify it, and it must be accompanied by a statement of intent that it will be (or is) deposited in a collection, and a statement indicating the name and location of that collection. Ideally, it should be lodged and registered in a public institution that is a recognized repository (i.e. museum of national/international standing). Deposition of types in public institutions is not mandatory for holotypes or lectotypes, only for neotypes, but it is strongly recommended. The size, sex (if applicable), and developmental stage should also be given. It is important to document the label data [i.e. locality (including geographical coordinates), altitude, date, collector name, and other collection details], registration number, and the name of the institution/collection in which the specimen is held. Publication of all information on the labels accompanying the holotype ensures that the specimen will be recognized in future.

Lectotypes and neotypes are treated similarly to holotypes. If a lectotype is being selected from two or more syntypes, then the specimen must be clearly labelled to ensure recognition. For lectotype designations to be valid, the term 'lectotype' must be used and the published work must contain a statement of the taxonomic purpose of the designation. In other words, the work must state that a lectotype is being designated for the first time so that it is clear that the name is being fixed to the species, for example, by the words 'new lectotype designation' or 'lectotype hereby designated'.

If no name-bearing type of a species-group taxon is believed to be extant (i.e. the holotype, lectotype, or syntypes are lost or destroyed), or if the existing name-bearing type cannot be determined so that the correct application of the name is in doubt (i.e. the name is a nomen dubium), a single specimen may be designated as a neotype, which then becomes the name-bearing type. However, designation of neotypes should be done only under exceptional circumstances in order to solve a complex taxonomic problem, not as a matter of curatorial routine; besides that, often at times 'lost' types have been rediscovered, invalidating carelessly proposed neotypes.

Once the holotype or lectotype has been fixed, labelled, and listed, it is essential to label all the remaining specimens examined, which automatically become paratypes or paralectotypes. The label data and repository of all paratypes or paralectotypes should then be listed in the paper. These types have no name-bearing function, but it is important to mention them because they provide material evidence that was used to inform the original description, diagnosis, and extent of variation. If, however, there are large numbers of specimens (which frequently happens in entomology), it may be prudent to be selective about the number of paratypes designated or to list them in an appendix or as online supplementary material/supporting information.

Other material: In studies where the status of a species has been reviewed, revised, synonymized, or transferred to a different genus, all other specimens examined and used in the differentiation of that species should be listed after the type material. It is important to list this material because it allows others to repeat and test your observations at some point in the future (i.e. check the primary material evidence on which the data was obtained).

Description

The description section is mandatory for new species, and it should be presented in telegraphic style in which non-essential grammar (verbs and adjectives) is omitted to save space. The description should include the standardized vocabulary and all the essential taxonomic characters used as the standard in the taxonomy of the group concerned (Winston 1999). For described species that involve name changes, or where the original description was found to be inadequate, a **redescription** may be necessary.

Diagnosis

The diagnosis should comprise a differential diagnosis that clearly provides information on how the species differs from most similar or closely related species based on at least one unique character state of a distinguishing character that is easily recognizable (Rheindt *et al.* 2023). The diagnosis section is always shorter than the description section. Winston (1999) and Borkent (2021) recommend that the diagnosis section should be brief, consisting of a minimal set of statements that provide clear and precise information that distinguish a given specimen from other species. That information is usually based on comparative morphological character states, but other evidence (e.g. DNA, immature stages, behaviour, and biology) that distinguishes the species can be used, although sometimes it is better to include this information in the remarks section (Šlapeta 2013) but not in the discussion.

Remarks

The taxonomic remarks or comments section is not mandatory, but it is highly recommended (Šlapeta 2013). It is generally used to make comments about the history of nomenclature, type material, and typification. Other information, such as history of discovery and distinguishing characters not listed in the diagnosis (e.g. immature stages, and reproductive structures), can be included in the remarks.

Etymology

The etymology section provides the derivation of the name, why it was chosen, and how it was composed (Winston 1999). It is only included for newly described taxa. Inclusion of the etymology is highly recommended but is not mandatory under the *Code*, although many journals require it. There are four main types of scientific names that taxonomists regularly use: (i) descriptive names; (ii) toponyms; (iii) eponyms; and (iv) miscellaneous names. Descriptive names are used to describe the appearance of a species or pertain to some distinguishing feature

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or combination of characters; they may be simple (as an adjective, or as a noun in apposition), or they may be compound in form (e.g. adverb-adjective, adjective-adjective, adjective-noun, noun-noun). Toponyms refer to geographical location names or landmarks, and they may be constructed as a noun or as an adjective. Eponyms or patronyms are bestowed to commemorate or honour a particular person, such as the discoverer (field collector) or someone who has made a significant contribution to the field of science. Miscellaneous names are essentially other names to the exclusion of categories (i)–(iii) listed above, such as cartoon or fictional characters that may nonetheless convey some properties of the species or an arbitrary combination of letters of the Latin alphabet provided it is pronounceable with vowels. A good source for Latin names is Brown's (1956) *Composition of Scientific Words*.

OTHER ELEMENTS OF A TAXONOMIC PAPER

A taxonomic paper should follow the standard format of a scientific research paper (Winston 1999). Thus, it still needs to include an abstract, introduction, methods, discussion, acknowledgements, and bibliography or references sections, and sometimes the results section. The **introduction** should clearly state the aims of the study, the reason for describing the new species in the first place, and include sufficient background information to place the work in context. The **results** section is particularly useful where the taxonomic revision is based on a phylogenetic hypothesis or morphometric data with statistical analyses. Some journals now include the results section before the formal taxonomic section. **Keys** to species are particularly useful for larger revisionary works and actually help inform the diagnoses of each taxon (Borkent 2021). Several other sections are often included in a taxonomic publication; they are not essential but add value to the overall quality of the science. For instance, sections on **variation** (including sample size used to establish the range of variation), **distribution**, **biology**, **ecology** (e.g. host associations), and **conservation status**, if known, are very useful. The **discussion** section is essential and must place the results in relation to the aim or purpose of the study, any questions raised or hypotheses advanced in the introduction, and place the study in broader context of other work. A succinct summary explaining how a particular taxonomic conclusion was reached based on evaluation of the available evidence is also very useful in the discussion.

Few taxonomic papers cite the species' concept adopted and the underlying criteria, and hence evidence required, to test those concepts (Cook *et al.* 2010, Yeates *et al.* 2011). The species' concept is important because different concepts can lead to vastly different conclusions based on the same evidence. For example, a set of metapopulations or lineage may be regarded as a single species under the biological species' concept but may be regarded as two or more sister-species under any one of the phylogenetic species' concepts, which can have profound implications for biodiversity conservation (Agapow *et al.* 2004, Isaac *et al.* 2004, Balakrishnan 2005, de Queiroz 2007, Garnett and Christidis 2017, Thiele *et al.* 2021). Thus, it is important to state in the **methods** the species' concept used so that it is clear to the reader how the conclusions regarding species' delimitation were reached based on interpretation of the available evidence (Cook *et al.* 2010). In addition to species' concepts, authors may have different views or opinions regarding the delineation of the species under investigation. These views may be either broad or narrow. Taxonomists with a broad species' concept (the so called 'lumpers') tend to recognize fewer species and more synonyms and the term *sensu lato* or *s.l.* may be given after the species' name or for the species complex, whereas taxonomists with a narrow concept (the so called 'splitters') tend to recognize more species and fewer synonyms and the term *sensu stricto* or *s.s.* may be applied to the residual species' name. Note, this is a different approach to polytypic species with several subspecies (subordinate taxa) in which the term *s.l.* may be used to refer to a species and all of its constituent subspecies, whereas the term *s.s.* refers only to the nominotypical subspecies.

DISCUSSION

Taxonomy is an essential activity based on the testing of hypotheses and delimiting or refining species boundaries of organisms (Mayr 1969, Mayr and Ashlock 1991, Yeates *et al.* 2011, Thiele *et al.* 2021). As new evidence is acquired, species boundaries may need to be refined, which inevitably leads to name changes, either through the delimitation and description of new species or alteration to the taxonomic status of species (Table 1).

Descriptive taxonomy is not a difficult science, but it is one in which it is very easy to make mistakes (Winston 1999), perhaps because it can be a laborious, tedious, and time-consuming scientific discipline, but also because authors, and editors, are frequently unaware of basic taxonomic procedures (Šlapeta 2013). Work that contains errors cannot be retracted once it is published, and either you or someone else will have to deal with the consequences (and likely embarrassment!). Good taxonomy requires an understanding of nomenclature (rules of the *Code*), a sound knowledge of the historical literature, and the whereabouts of type material. Before revising or describing anything as new, a few simple steps ought to be followed (Table 3). First, conduct taxonomic research using all available specimens and other resources. Once the scientific research is completed and taxonomic conclusions have been reached in relation to proposed species hypotheses (Table 1), then determine how the names ought to be used (steps 2–4). A good understanding of nomenclature necessitates being familiar with rules, recommendations, and terminology of the ICZN (1999) (step 2). Then develop a list of all available names that have been published based on review of the primary taxonomic literature of the species and all similar or closely related species containing the original descriptions of those species (step 3). It is crucial to ensure that your species has not previously been named and described, and your newly proposed name has not previously been used—otherwise you may end up creating a junior synonym or a junior homonym that is unavailable or invalid. Then locate and examine, and preferably photograph, the type specimens (if they exist), especially the name-bearing types, pertaining to those names so that the identity of each available name is clearly established (step 4). This step is crucial because it ensures that the names and identities of species have been correctly established.

The next tasks (steps 5–10) are more operational and include constructing the new species' name correctly, designating a holotype and illustrating it, preparing the description and

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Table 3. Guidelines for the description of a new species based on 11 practical steps (modified from Šlapeta 2013).

Step 1	Conduct taxonomic research and determine species boundaries in relation to testable and falsifiable hypotheses.
Step 2	Become familiar with rules, recommendations and terminology of the *International Code of Zoological Nomenclature*.
Step 3	Review primary taxonomic literature and collate all available names (i.e. previously described names) and descriptions of similar species.
Step 4	Examine (and photograph) type material of available names of similar species.
Step 5	Construct new species' name correctly.
Step 6	Select holotype (name-bearing type specimen) that is representative of new species.
Step 7	Prepare high quality illustrations of type material, especially holotype.
Step 8	Prepare description according to accepted taxonomic standards for the taxon group.
Step 9	Prepare differential diagnosis based on comparative evidence.
Step 10	Register manuscript (and preferably new species' name) in ZooBank for electronic-only publication.
Step 11	Publish research findings in reputable taxonomic journal.

diagnosis, and registering the title and author(s) of the manuscript in ZooBank for electronic-only publications. Finally, once the manuscript is complete, publish your findings in a reputable peer-reviewed scientific journal that has a track record of publishing quality systematic works or an Editorial Board that is familiar with taxonomic procedures (step 11). These publications take on many forms, from short papers describing a single species to systematic revisions and large monographs revising numerous species within a higher taxonomic group. Although there is no requirement for taxonomic works to be published in peer-reviewed scientific journals, scientific best practice is to publish authoritative taxonomic papers in refereed journals (Wüster and Kaiser 2023)—the peer-review process is by far the best mechanism to control the quality of publications on taxonomy.

Despite these simple guidelines (Table 3), we have observed that a number of taxonomic publications in recent decades fall short of the basic procedures and minimum standards required for naming new taxa. We provide some examples of a number of pitfalls and mistakes to avoid in relation to several mandatory provisions and recommendations of the *Code* and accepted standards of taxonomic best practice and journal editorial policy. Our examples are mainly from the insect order Lepidoptera, particularly butterflies (Papilionoidea), because this taxon group seems to be rife with 'malpractice', but examples from other groups with high levels of 'malpractice', such as reptiles and amphibians (Wüster *et al.* 2001, Kaiser 2013, 2014, Kaiser *et al.* 2013, Wüster *et al.* 2021, Denzer and Kaiser 2023, Wüster and Kaiser 2023), are given.

Failure to read the *Code*

Once the species boundary or delimitation has been established it is crucial to have a good working knowledge of the rules and recommendations of the *Code* to ensure that new names are code compliant. However, it is apparent that some authors are simply not aware that a code of zoological nomenclature even exists. For example, Gu *et al.* (2023) proposed the name *Manis mysteria* Gu *et al.*, 2023 (Pholidota: Manidae) for a new cryptic species of pangolin discovered in China; however, they neither clearly indicated that the name was intended to be new (Article 16.1) nor designated a holotype (Article 73), and, moreover, they did not provided a description (Article 13). Despite the authors intentions, noting that 'In the future, a formal taxonomic description and nomenclature will require the discovery of whole animals and a type specimen', *Manis mysteria* Gu *et al.*, 2023 is not available because it contravenes numerous provisions of the *Code*, suggesting the authors were not aware of basic taxonomic procedures regardless of the quality of their science, which was published in the journal *PNAS*. Similarly, Lamb (2023) recently proposed the name *Vanessa kiwa* Lamb, 2023 for a putative new species of nymphalid butterfly from New Zealand's North Island (Poverty Bay). Although the name of the new species was latinized, there was no explicit intention to indicate that the taxon was new (Article 16.1), no designation of a holotype (Article 73), no explicit statement to indicate in which collection name-bearing type material is located (Article 16.4), and no description or differentiation (Article 13), just a vague comparison with the two subspecies of *Vanessa gonerilla* (Fabricius, 1775) that hardly justified a 'diagnosis'. Beside the fact that the taxonomic literature was not reviewed or type material of *V. gonerilla* was examined, the name *V. kiwa* Lamb, 2023 is unavailable because the mandatory provisions of the *Code* were not followed. We expand on these and other non-compliance issues below.

Failure to review the primary taxonomic literature

Failure to compile a list of available names (synonyms) based on review of the taxonomic literature can result in enormous problems for other workers. For example, Miller (1995) published a checklist of the neotropical Castniidae (Lepidoptera), but it became apparent that the primary taxonomic literature had not been examined, which resulted in numerous inaccuracies, including omissions of available names, misspellings, wrong authority citations, incorrect dates of publication, and incorrect type localities (Lamas 1995). A consequence of this inaction was taxonomic misinformation and inflation—the 134 species recognized in Miller's list were reduced to 81 species in Lamas' list, largely due to synonymy.

Article 23 of the *Code* sets out the Principle of Priority. The valid name of a taxon is the oldest available name (the senior synonym) applied to it. The purpose of this provision is to provide nomenclatural stability in cases in which a taxon has two or more names bestowed upon it. This duplication of names happened frequently in historical times due to taxonomists working on the same species in different places or countries, or

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through the description of different sexes as different species. The easiest way to avoid duplicating species' names and creating nomenclatural confusion is to become familiar with all of the available names published in the taxonomic literature. However, even in modern times there are still cases in which known species are being named and described. For example, Fujioka (1992) described the butterfly *Laeosopis praetextatus* Fujioka, 1992 (Lycaenidae), but in the following year D'Abrera (1993) described the same species under the name *Laeosopis hoenei* D'Abrera, 1993. Under Article 23 of the *Code*, Fujioka's name is available and valid (senior synonym), whereas D'Abrera's name is available but invalid (junior synonym). In other cases, synonyms arise from competition between taxonomists working on the same taxa, a practice strongly discouraged by the *Code* under its Code of Ethics. For example, Yago (2004) was undertaking a systematic revision of the butterfly subtribe Horagina (Lycaenidae) and the finished work included the description of a new species, *Horaga uedai* Yago, 2004, which was published on 20 January 2004. However, Saito and Seki [2004] described the same species, under the name *Horaga takanamii* Seki & Saito, [2004], a few weeks earlier by side-stepping the peer-review process and publishing in a magazine [issue Number 38 of *Butterflies* was released to its members on 1 January 2004 (U. Yoshinobu, pers. comm.)]. Thus, the valid name for the species is *Horaga takanamii* Seki & Saito, [2004] (senior synonym) and not *Horaga uedai* Yago, 2004 (junior synonym).

Article 52 of the *Code* sets out the Principle of Homonymy. The purpose of this provision is to ensure that two or more different taxa are not denoted by the same name. In such cases, only the oldest name (the senior homonym) can be used as the valid name. For example, Lambert *et al.* (2010a) described a new genus of fossil sperm whale from the Miocene of Peru in the prestigious journal *Nature*, not realizing that the name *Leviathan* Lambert *et al.*, 2010 (junior homonym) was pre-occupied by a mammoth *Leviathan* Koch, 1841 (senior homonym), thus rendering their new genus name unavailable. The authors subsequently published a corrigendum Lambert *et al.* (2010b) and proposed *Livyatan* Lambert *et al.*, 2010 as a replacement name for *Leviathan* Lambert *et al.*, 2010. In another example, Fujioka (1993) described the butterfly subspecies *Ravenna nivea howarthi* Fujioka, 1993 (Lycaenidae) in a paper dated 15 April 1993, not realizing that the same name had been used for the same taxon a month earlier by Saigusa (1993), as *Ravenna nivea howarthi* Saigusa, 1993 published on 5 March 1993. Thus, *Ravenna nivea howarthi* Fujioka, 1993 is a junior homonym (and a junior synonym) of the valid name *Ravenna nivea howarthi* Saigusa, 1993, which is the senior homonym (and senior synonym).

To avoid creating junior synonyms or junior homonyms, three useful resources to check for names are:

- Nomenclator Zoologicus (Neave 1939–40, 1950–1975): http://insecta.bio.spbu.ru/z/nomenclator_zoologicus_PDF.htm
- Zoological Record: https://clarivate.com/products/scientific-and-academic-research/research-discovery-and-workflow-solutions/webofscience-platform/web-of-science-zoological-records/
- Google Scholar: https://scholar.google.com/

Failure to examine type material

Recommendation 73B (Preference for specimens studied by author) of the *Code* states 'An author should designate as holotype a specimen actually studied by him or her, not a specimen known to the author only from descriptions or illustrations in the literature'. Denzer and Kaiser (2023) recommended that best taxonomic practice is for authors to include a statement in their manuscript indicating that type specimens were physically examined in order for their publications to be acceptable for the purposes of zoological nomenclature. The main reasons for examining type material are to ensure that the nomen of the taxon has been correctly applied by subsequent workers, and that the name-bearing type is identifiable. If the name-bearing type is indeterminate, an author may request the Commission, under its plenary power, to replace the unidentifiable name-bearing type with a neotype (Article 75.5). However, there are numerous examples in the literature in which authors undertaking taxonomic revisions fail to examine name-bearing type material. Such actions are not in breach of the *Code*, but it is poor taxonomic practice not to examine type material. For example, in a systematic revision of the butterfly genus *Taractrocera* Butler, [1870] (Hesperiidae) based on comparative morphology, de Jong (2004) did not examine type material of the species *Taractrocera ilia* Waterhouse, 1932. At that time the species was considered to be polytypic, composed of two subspecies: the nominotypical subspecies from northern Australia, and *T. ilia beta* Evans, 1934 from mainland New Guinea. De Jong (2004) only examined material of the subspecies *T. ilia beta* for the diagnosis of the species *T. ilia.* More seriously, types of neither subspecies were examined. Subsequent examination and comparison of the types of both subspecies revealed that *T. beta* Evans, 1934 is, in fact, a species distinct from *T. ilia* (Braby and Zwick 2015), leading to an erroneous diagnosis of *T. ilia* in the earlier study.

Failure to construct the taxon name correctly

Articles 31–34 of the *Code* deal with the formation of species-group names, original spellings, and subsequent spellings. The scientific name (genus- and species-group) must be in Latin or latinized (Article 11.9), with correct endings when formed from personal names (Article 31.1). However, some authors fail to follow these rules. For example, the snake *Acanthophis wellsei* Hoser, 1998 was described in honour of Richard Wells. However, this name was improperly constructed because under the *Code* the genitive ending for a man is '*i*' and for a woman is '*ae*' (Article 31.1.2). The name was subsequently redescribed and emended to *Acanthophis wellsi* Hoser, 1998 by Aplin and Donnellan (1999), although this action is an unjustified emendation, and the name *A. wellsi* should be regarded as an incorrect subsequent spelling and, therefore, unavailable (Articles 33.3, 33.4), even though the original spelling was erroneous. Other examples of erroneous endings constructed by herpetologists that required emendation (Articles 33.2, 50.4) were reviewed by Wüster *et al.* (2001).

Ethics: Some names are particularly cumbersome or poorly constructed and difficult to pronounce. Long-winded names such as the amphipod *Gammaracanthuskytodermogammarus loricatobaicalensis* Dybowski, 1926 are not particularly helpful in terms of providing clear and unambiguous communication.

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Although *G. loricatobaicalensis* was technically available under the Principle of Binominal Nomenclature (Article 5), the work where it was published was suppressed for nomenclatural purposes by the ICZN under its plenary powers (Opinion 105, Direction 32), and thus the name is unavailable. The *Code* recommends that 'Authors should exercise reasonable care and consideration in forming new names to ensure that they are chosen with their subsequent users in mind and that, as far as possible, they are appropriate, compact, euphonious, memorable, and do not cause offence' (Recommendation 25C. Responsibility of authors forming new names). Although it is not explicitly stated in the *Code*, it is considered unethical to name a species after yourself, but it does happen. For example, Wall (1907) named the snake *Bungarus walli* Wall, 1907 after himself and, more recently, Kaiser *et al.* (2013) identified an author who named no less than 43 eponyms that included his surname.

Eponyms: Recent proposals to change names, particularly eponyms, on ethical grounds (Hammer and Thiele 2021, Guedes *et al.* 2023), or to replace long-established scientific names with new indigenous names (Gillman and Wright 2020), have been rejected by the taxonomic community (Ceríaco *et al.* 2023). Such proposals contravene the fundamental aim of the *Code*, which is to promote nomenclatural stability and universality without constraining taxonomic judgement.

Failure to explicitly establish the new taxon

Article 16.1 of the *Code* states that every new name published after 1999 must be explicitly indicated as intentionally new. Authors are advised to make their intentions explicit by using in the heading of new names abbreviations of Latin terms, such as 'fam. nov.', 'gen. nov.', 'sp. nov.', 'ssp. nov.', or an equivalent expression (e.g. 'species nova', 'new species'). Failure to follow Article 16.1 will render the new name(s) invalid. For example, Stradomsky (2016) proposed several new subtribes of polyommatine butterflies (Lycaenidae) (i.e. Pithecopina Stradomsky, 2016, Azanina Stradomsky, 2016, Theclinesthina Stradomsky, 2016, Jamidina Stradomsky, 2016, Uranothaumatina Stradomsky, 2016, Zizulina Stradomsky, 2016, Oboroniina Stradomsky, 2016, and Fameganina Stradomsky, 2016), but he did not explicitly indicate that the names were intentionally new, thus failing Article 16.1 (All names: intention of authors to establish new nominal taxa to be explicit). Moreover, he did not cite the type genus for each taxon, thus failing Article 16.2 (see typification below).

Failure to provide adequate typification

Articles 61–75 of the *Code* deal with the Principle of Typification, which applies to nominal taxa in the family, genus, and species groups. For family-group names, the name-bearing type is the 'type genus' (Article 63); for genus-group names, the name-bearing type is the 'type species' (Article 67); and for species-group names, the name-bearing type is the 'holotype' or syntypes (Article 73), 'lectotype' (Article 74) or 'neotype' (Article 75). For all taxa described after 1930, failure to designate a type genus for a new family-group name or a type species for a new genus-group name will render the taxon name unavailable. For example, Grund (1998) and Atkins (2005, 2012, 2017) collectively proposed 11 tribal and subtribal names for the butterfly subfamily Trapezitinae (Hesperiidae), *viz*: Mesodinini Grund, 1998; Hesperillini Grund, 1998; Trapezitini Grund, 1998; Proeidosini Atkins, 2005; Mesodinina Atkins, 2012; Hesperillina Atkins, 2012; Toxidina [sic] Atkins, 2012; Trapezitini Atkins, 2012; Anisyntina Atkins, 2017; Proeidosina Atkins, 2017; Toxidini [sic] Atkins, 2017. However, for each higher taxon no type genus was given. Thus, these names are not available because the proposals contravene the rules of the *Code* for typification of types in the family group (Article 63. Name-bearing types) and names published after 1999 (Article 16.2. Family-group names: type genus to be cited). There were also other issues with these names, for instance, the authors failed to provide a diagnosis (nomina nuda—see diagnosis below), or construct the name correctly, or the names were junior synonyms and homonyms (Toussaint *et al.* 2022). For instance, Hesperillini Grund, 1998 and Hesperillina Atkins, 2012 are junior synonyms and homonyms of Hesperillini Voss, 1952, and Trapezitini Grund, 1998 and Trapezitini Atkins, 2012 are junior synonyms and homonyms of Trapezitinae Waterhouse & Lyell, 1914.

At the species-level, the name-bearing types (holotype, lectotype, neotype, or syntypes) are particularly important because they fix the name to the species (Articles 72–75). When describing a new species, it is now mandatory to designate a holotype. Furthermore, it is advisable to lodge the type specimen in an institutional collection and give the name of the institution in which it has been deposited (Recommendation 16C. Preservation and deposition of type specimens). When designating a holotype for a new species, it is essential to select a specimen that is representative of the species, that is, one that shows most, or all of the diagnostic characters of the species. Other type material should also be listed correctly and referred to as paratypes, not as 'cotypes' (Recommendation 73E. Avoidance of the term 'cotype') or 'topotypes' (specimens originating from the type locality), although the *Code* does allow use of the term 'allotype' to indicate a specimen of opposite sex to the holotype (Recommendation 72A. Use of the term 'allotype'). Failure to provide adequate typification will render the name unavailable. Moreover, failure to comply with the requirements of Article 16.4 (fixation of name-bearing types for species-group names to be explicit) will make names published after 1999 unavailable—there are several cases of authors who have forgotten to provide statements about the name(s) and location(s) of the collection(s) where the holotypes are (or will be) deposited. For example, Viloria *et al.* (2003) proposed a new species of butterfly, *Redonda bordoni* Viloria & Pyrcz, 2003 (Nymphalidae), from the high Andes of South America in the *Proceedings of the Royal Society of London*. They provided a diagnosis; however, the description was relegated to an online appendix, which is no longer accessible. More seriously, however, no type data and no repository for type material were provided. Thus, the name *Redonda bordoni* Viloria & Pyrcz, 2003 is unavailable because it does not satisfy the provisions of Article 16.4.

Type material: We recommend that types be based on preserved material deposited in collections, rather than on photographs of live animals (i.e. photography-based taxonomy—Donegan 2008, Pape 2016, Thorpe 2017), because specimens are the primary evidence on which names are based. They also provide far more characters for an objective diagnosis and description, evidence

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that can be verified and replicated by future workers, than secondary evidence from photographs (Dubois and Nemésio 2007, Krell and Wheeler 2014, Rocha *et al.* 2014, Ceríaco *et al.* 2016, Krell and Marshall 2017). Perhaps the most notorious example of photography-based taxonomy is the description of the infamous Loch Ness Monster *Nessiteras rhombopteryx* Scott & Rines, 1975, a hoax published in *Nature*. Irrespective of the organisms lack of biological reality (Halstead *et al.* 1976, Lawton 1996), Scott and Rines (1975) provided no name-bearing type, with the entire description based on a rather poor set of photographs of purported animal parts of a plesiosaur-like reptile, all of which have since proven to be fraudulent (Campbell 1986, Ohl 2018). One of the cornerstones of scientific work is repeatability, and specimens lodged in a museum allow other researchers to examine them so that the observations can be repeated. For instance, if future research reveals that taxonomic changes need to be made (e.g. presence of a second, cryptic species based on new evidence), the holotype specimen can be re-examined for verification and acquisition of additional data, a task that may not be possible from photographs (Ceríaco *et al.* 2016). Museum specimens also provide opportunities for future research in ways yet to be realized with the emergence of new technologies (Krell and Wheeler 2014, Rocha *et al.* 2014). However, we acknowledge that the preservation of complete specimens may not always be possible, particularly for threatened species that have exceedingly low population numbers, such as the recently discovered, and described, Galapagos pink land iguana *Conolophus marthae* Gentile & Snell, 2009 from the Galapagos Islands (Donegan 2009, Gentile and Snell 2009), although in such cases the collection of a single or a few specimens to serve as types is not likely to cause extinction (Rocha *et al.* 2014). Type specimens should never be permanently deposited in private collections due to the risk of them being lost or destroyed when the owner of the collection dies or the collection is broken up (Knapp *et al.* 2004). Some journals demand that type and other specimens are lodged in public institutions.

Failure to differentiate the new taxon

Article 13 of the *Code* sets out the requirements for new names published after 1930. For new names to be available they must 'be accompanied by a description or definition that states in words characters that are purported to differentiate the taxon' (Article 13.1.1). Further, the *Code* goes on to say that 'When describing a new nominal taxon, an author should make clear his or her purpose to differentiate the taxon by including with it a diagnosis, that is to say, a summary of the characters that differentiate the new nominal taxon from related or similar taxa' (Recommendation 13A. Intent to differentiate). Names published after 1930 that fail to conform to Article 13 are not available and are known as nomina nuda (singular nomen nudum). Thus, for a new species, the description and diagnosis need to be useful and to convince the reader that the new species is biologically meaningful and can be justified. That justification is based on evidence, which is the data used to test species boundaries and to delimit the species. This evidence may include morphological, molecular (Tautz *et al.* 2003, Cook *et al.* 2010), biological, ecological, or behavioural characters, and ideally an integrative approach that combines traits from all of these data sources (Will *et al.* 2005, Wiens 2007). In other words, the diagnosis should provide sufficient information to allow anyone to distinguish the new species from similar or closely related species (Rheindt *et al.* 2023). However, some authors fail to provide this information. For example, in revising the diverse Neotropical butterfly genus *Catasticta* Butler, 1870 (Pieridae), Reissinger (1972) divided the genus into several subgenera, of which four were new (*Archonoia* Reissinger, 1972, *Pierinoia* Reissinger, 1972, *Leodontoia* Reissinger, 1972, and *Hesperochoia* Reissinger, 1972). However, Reissinger (1972) did not provide descriptions or diagnoses for them and thus they are nomenclaturally unavailable (Wojtusiak 1998, Lamas and Bollino 2004). Subsequently, Eitschberger and Racheli (1998) recognized two of Reissinger's names, *Leodontoia* and *Hesperochoia*, as distinct genera and provided putative distinguishing characters, thus inadvertently making them available. Therefore, the available names are now credited to Eitschberger and Racheli (1998), as *Leodontoia* Eitschberger & Racheli, 1998 and *Hesperochoia* Eitschberger & Racheli, 1998, rather than to Reissinger (1972). Similarly, Smart (1975) established the subgeneric name *Antipodolycaena* Smart, 1975 for the New Zealand coppers *Lycaena* Fabricius, 1807 (now placed in the genus *Boldenaria* Zhdanko, 1995). Smart (1975) published the name in an appendix of a popular book and listed *Lycaena boldenarum* White, 1862 as the type species, but he did not provide a diagnosis or description (he just stated '… certain small but significant differences in pattern element, particularly on the undersides...'). Hence, *Antipodolycaena* Smart, 1975 is not available because it does not satisfy the provisions of Article 13.

Many authors of taxonomic papers prepare the diagnosis as a shortened version of the description without comparison to other similar species, and thus the diagnoses fail to be contrastive and/or state-specific (Rheindt *et al.* 2023). We discourage such poor taxonomic practice because the goal of a differential diagnosis is to clearly specify which character states, of one or more characters, distinguish the species from other species.

Failure to register the publication in ZooBank

For electronic publications, the work describing the new name must be registered in ZooBank for it to be available (Yeates 2009, Rosenberg *et al.* 2012, Zhang 2012, Krell and Pape 2015, Braby 2018). However, following the amendment of the *Code* by the ICZN (2012), there have been hundreds, if not thousands, of examples of new species published in e-journals where this has not happened (M.S. Harvey, pers. comm.). For example, the paper describing a new species of frog (*Buergeria otai*) from Taiwan in *PLoS ONE* (Wang *et al.* 2017) was not registered in ZooBank and thus the name is not available. The authors subsequently resubmitted to the same journal a correction (Wang *et al.* 2018), which included the ZooBank registration number, but they inadvertently omitted details concerning the description and typification, so that the name constituted a nomen nudum (an unavailable name—see diagnosis above) with no holotype (see typification above). The authors finally made the name of their new species available by sidestepping the ZooBank registration altogether and publishing the description (in Chinese and English) in the print (hard copy) magazine *Nature Conservation Quarterly* (Wang *et al.* 2020). Hence, the correct nomenclature for the species is *Buergeria otai* Wang *et al.*, 2020 and not *Buergeria otai* Wang *et al.*, 2017, but it took three attempts!

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Failure to publish the new taxon name

Article 8 of the *Code* sets out the criteria to be met for new names to be published. A published work 'Must be issued for the purpose of providing a public and permanent scientific record, must be obtainable free of charge or by purchase, and must have been produced in an edition containing simultaneously obtainable copies by a method that assures numerous identical and durable copies' (Article 8.1). Further, the *Code* recommends that new scientific names ought to be published in journals that will be captured by the *Zoological Record* database. Names printed in abstracts or posters at conference meetings or congresses, or manuscript names placed on a label attached to a specimen, or photographs, or names posted on the Internet are considered unpublished and, therefore, are not available. For example, C. Lee coined the name *Luehdorfia longicaudata* for a new and endangered butterfly from the Qinling Mountains in China in an oral presentation at the 28th annual meeting of the Lepidopterological Society of Japan in 1981, but the name is not available since it was not published according to the rules of Article 8. However, the following year, an abstract of his lecture concerning the geographical distribution and habitat of the new species, together with a brief description and comparison with two other species of *Luehdorfia* Krüger, 1878 from China, appeared in print in a non-peer-reviewed news bulletin (translated in Japanese) (Lee 1982). Thus, the valid name for this species is *Luehdorfia longicaudata* Lee, 1982 and not *Luehdorfia longicaudata* Lee, 1981 or *Luehdorfia taibai* Chou, 1984, a proposed replacement name (nomen novum) (Inomata 1995), even though the publication process was convoluted and scientifically poor.

The *Code* does not explicitly exclude new names from availability in higher degree theses and dissertations, but most taxonomists have generally assumed that they do not constitute published works within the provisions of Article 8 of the *Code* unless they are issued 'For the purpose of providing a public and permanent scientific record' (Article 8.1.1); they are 'Obtainable, when first issued, free of charge or by purchase' (Article 8.1.2); and they are 'Produced in an edition containing simultaneously obtainable copies by a method that assures numerous identical and durable copies' (Article 8.1.3). If these provisions are not satisfied, authors should regard theses and dissertations as unpublished work.

Other issues of 'malpractice'

Taxonomic vandalism: Taxonomy is perhaps the only field of science in which there is no requirement for its scientific products to be published through the critical peer-review process (Wüster *et al.* 2021). Although there have been proposals to change the rules of the *Code* so that new species can be described only through a formal accreditation process, such as in peer-reviewed journals (Borrell 2007, Yeates 2009, Kaiser 2013, Kaiser *et al.* 2013, Denzer and Kaiser 2023, Wüster and Kaiser 2023), these recommendations have yet to be endorsed and implemented by the ICZN. Thus, taxonomic works may be published privately in self-published works, which potentially opens the door to poor-quality work or even non-scientific work. For example, in the past four decades (since 1984) over 2000 new names of reptiles and amphibians have been published in non-accredited outlets by two authors, of which *c.* 90% have been published since 2000 (see reviews by: Aplin 1999, Wüster *et al.* 2001, Williams *et al.* 2006, Kaiser *et al.* 2013, Kaiser 2014, Wüster *et al.* 2021). Although the names are technically available according to the rules of the *Code*, the robust scientific evidence upon which they should have been established was fundamentally lacking—for instance, the descriptions and diagnoses were inadequate, often failing to demonstrate the biological validity or the reality of the species concerned, or the authors designated type specimens that they had not examined (contravening Recommendation 73B), such as through nomenclatural harvesting of phylogenetic clades (Denzer and Kaiser 2023). Such mass-naming or mass-changing of taxa based on poor or non-scientific practice is known as 'taxonomic vandalism' (Kaiser *et al.* 2013, Wüster *et al.* 2021). Proposals to declare names and nomenclatural acts published in controversial taxonomic works as unavailable through the *Code's* requirements for publication have been rejected by the ICZN because the proposals are a direct violation of the *Code* (Krell 2021). Instead, such works are best resolved by prevailing usage within the scientific community who will either accept or reject the proposed taxonomy. In the case of reptiles, the herpetological community has recommended not to adopt the names proposed by 'taxonomic vandals' (Kaiser 2013, 2014, Kaiser *et al.* 2013). Moreover, Wüster *et al.* (2021) have proposed a new concept to deal with such extreme acts of taxonomic vandalism—they coined the term 'aspidonyms', which are scientific names proposed to overwrite unscientific names established by non-scientific methods as a last resort to stabilize scientific nomenclature. The aspidonyms are either senior synonyms or replacement names (junior synonyms), but it remains to be seen what position the ICZN adopts on the matter of taxonomic vandalism.

Fake holotypes: Fabricated or fictitious types based on fake species are particularly serious and hinder the advancement of scientific knowledge—they simply add to the burden of junior synonyms that someone else has to resolve (Ohl 2018). Yet, there are several examples of species, especially butterflies, in which new species have been described and published based on fakes—we know of at least nine in the past few decades (Johnson and Matusik 1988, 1989, Okano 1989, Johnson 1990, 1992, Johnson *et al.* 1990, 1997). In these cases, the holotypes of the fake species were actually composite specimens, created by joining parts belonging to different species, often belonging to different genera (and sometimes from different biogeographical regions). Under the provisions of Article 1.3 of the *Code*, names of species based on hypothetical concepts may be excluded (i.e. a taxonomic concept that when published contained no animal then known to exist in nature, past or present). In addition, under the provisions of Article 73.1.5 of the *Code*, parts of the chimeric holotypes may be excluded from the holotype to clarify identification of the name in order to recognize it as a junior synonym (Yagishita *et al.* 1993, Peggie *et al.* 1995, Robbins and Nicolay 1999, Robbins and Lamas 2002, Bálint and Benyamini 2020). In other cases, the holotypes of fictitious species were manufactured by applying paint to specimens of known species to give an entirely different appearance (Vane-Wright and Whalley 1985) or the holotype was stolen and replaced with a fake comprising a painted specimen of a different species (Braby and Eastwood 2019).

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CONCLUSION

Taxonomy lays the foundation for all of the biological sciences, including ecology, evolutionary biology, biodiversity conservation, biosecurity, primary industry, medicine, and public health. However, the prevalence of poor taxonomic practice and even 'malpractice' (taxonomic vandalism, fictitious species based on fake types) indicates a need for consistency in the procedure and quality of taxonomic research publications dealing with the description of new species, changes of species' names (i.e. synonymy, status revision, new combination), and nomenclatural acts (typification). Authors (and editors) need to be aware of basic taxonomic procedures and be familiar with the sets of rules and principles at four different levels: (i) articles of the current *International Code of Zoological Nomenclature*; (ii) recommendations of the *Code*; (iii) accepted standards of taxonomic best practice of the taxon group; and (iv) journal editorial policy and author guidelines. Robust taxonomy requires an understanding of nomenclature (rules and recommendations of the *Code*), familiarity of the primary taxonomic literature, and the whereabouts of name-bearing type material, which ought to be physically examined. Moreover, descriptions of new species should construct the taxon name correctly, explicitly establish the new taxon, provide adequate typification, clearly differentiate the new taxon, and publish the name of the new taxon in a manner that is compliant with the *Code*, preferably in an authoritative peer-reviewed scientific journal. It is recommended that the taxonomic section of a taxonomic publication include the following elements: classification header (including type species of the genus-group name); species' name header in binominal form, followed by the term 'sp. nov.' or 'sp. n.' for new species, or the authority citation, date of publication, and kind of taxonomic change being made for described species being revised; figure references (illustrations of name-bearing type), ZooBank registration number (for papers published in electronic-only journals), type locality, and the synonymy section; material examined (including type material, and other material); description; diagnosis; remarks (including, but not limited to, history of nomenclature, type material, typification, and history of discovery); and the etymology of new taxa.

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